The Economic Rationale for Infection-Control in Australian Hospitals

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Abstract

Objective: To predict the economic consequences of healthcare-acquired-infections arising among admissions to Australian acute care hospitals.

Methods: A quantitative algorithm informed by epidemiological and economic data was developed. The setting is all acute care hospitals in Australia and the participants described are all admissions to general medical and general surgical specialties. The main outcome measures are the numbers of cases of healthcare-acquired-infection and bed days lost annually.

Results: There are a predicted 175,153 (95% Credible Interval 155,911:195,168) cases of healthcare-acquired infection among admissions to Australian hospitals annually, and the extra stay in hospital to treat symptoms accounts for 854,289 bed days (95% Credible Interval 645,091:1,096,244). If rates were reduced by 1%, then 150,158 bed days would be released for alternative uses. This will allow approximately 38,500 new admissions.

Conclusions: Healthcare-acquired-infections arising among patients blocks beds in Australian hospitals. The cost-effectiveness of hospital services might be improved by allocating more resources to infection control, releasing beds and allowing new admissions.

Implications: There exists an opportunity to improve the efficiency of the Australian health care system.

Introduction

Acute hospitals in Australia cannot meet current demand. Waiting lists for elective surgery and specialist outpatient appointments are lengthening in every state and territory. In 2004/05 ninety percent of patients from waiting lists for elective surgery were admitted within 217 days compared to 197 days for 2002/03 (1). Two forces are at work. The first is that health needs are increasing. The emergence of novel and effective therapies alongside a population with increasing age and morbidities contribute (2, 3). The second is that healthcare is becoming relatively more expensive. Compared to other production processes that comprise a modern industrialised economy, healthcare is relatively labour intensive and has been described as a 'handicraft industry' (4). The result is that every dollar spent on healthcare is buying less output as compared to other industries. The costs of supplying healthcare services are rising and this partly explains the growth in expenditures among developed countries, including Australia (5).

What remedies are available? The default policy is to leave people on waiting lists, and manage demand with queuing. One sensible policy is preventive health strategies such as 'quit smoking' and 'primary prevention of diabetes' but these will not completely compensate for increasing needs and costs. The supply of hospital bed days could be increased by building more hospitals. This is expensive and requires workers to be trained to operate new facilities. An alternative is to improve the cost-effectiveness of health services by increasing output for the same stock of bed days. This could be achieved by reducing the number of bed days used by each patient. There are many reasons why patients stay in hospital and use bed days (6). Factors such as age, frailty and underlying illnesses cannot be changed when the patient is admitted to hospital. However, the risk of adverse events during the hospital admission that

increase length of stay - such as falls, pressure ulcers, prescribing errors, cardiac arrests and healthcare acquired infection (HAI) - can be reduced by effective intervention.

Three objectives are addressed by this paper: to estimate the number of cases of HAI and the number of bed days lost to HAI for a 12 month period among all Australian hospitals; to report these results by site of infection and state/territory; and, to estimate the number of bed days that would be gained or lost if there were less or more cases of HAI; this simulates changes to the effectiveness of infection control. These objectives are addressed by using a quantitative algorithm. It takes a logical structure, is informed with appropriate information and uncertainties among parameters are propagated forward to the conclusions. The findings can be used to inform decision making about the allocation of resources to infection control programmes.

Method

The algorithm shown in Figure 1 has two primary outcomes for a 12 month period: the number of hospitalised patients with HAI, marked (A); and the number of bed days lost to HAI, marked (B). Data are required for three parameters to estimate these outcomes:

i) the number of patients at risk of HAI

ii) the incidence rates of HAI

iii) the extra length of stay associated with HAI.

The number of cases of HAI (marked A) is estimated from (i) and (ii) and the number of bed days lost to HAI for the 12 month period (marked B) is estimated from A and (iii).

FIGURE 1 HERE

number of patients at risk of HAI

Data on hospital activities in 2004-05 by state and territory were obtained from the Australian Institute of Health & Welfare (1). The number of admissions to Australian hospitals was estimated by adjusting for multiple separations. These data are provided by regional health services and represent a census of hospital activity.

incidence rates of HAI

Information on the incidence rates for healthcare-acquired urinary tract infection (UTI), lower respiratory tract infection (LRTI), blood stream infection (BSI), surgical site infection (SSI), 'other' single sites of infection (OTHER) and cases of patients who acquired more than one infection during their admission (MULTI) were obtained from a prospective cohort study undertaken in two Australian hospitals in 2002/03 (7-9).

extra length of stay associated with HAI

Estimates of statistical association between HAI and length of stay outcomes in the Australian setting are available for healthcare acquired UTI, LRTI and OTHER single sites of infection (7), for SSI (8) and for MULTI infection (9).

evaluation of data

Beta distributions are fitted to the parameters that describe incidence rates and gamma distributions are fitted to the parameters that describe extra length of stay parameters (see Appendix 1 for details). Five thousand random samples were taken from the distributions that describe the incidence rates and the additional lengths of stay associated with HAI. For each re-sample a value for the outcomes 'number of cases of HAI' and 'number of bed days lost to HAI' were calculated and recorded. This process formed a posterior distribution of these outcomes and so propagates forward the uncertainties in parameters to conclusion. The

credible intervals reported contains the true value with a 95% probability. A 95% confidence interval contains the true value on 95% of occasions, if the random process could be repeated. By definition, a 95% confidence interval misses the true value on 5% of occasions. 95% confidence intervals are often interpreted as if they were credible intervals (10). Although a 95% credible interval is often very similar to a 95% confidence interval, credible intervals are far more intuitive to interpret which is why we used them here. Rates of HAI were then artificially increased and decreased by 1%, and the algorithm updated, to simulate the effects of having more and less infection control.

Results

The total number of patients at risk of any HAI in 2004/05, and the number treated in a surgical speciality, are summarised in Table 1.

TABLE 1 HERE

The incidence rates for HAI among 4,488 admissions to Australian hospitals over 95 days are shown in Table 2.

TABLE 2 HERE

There were 228 cases of infection among the 4,488 admissions giving an overall incidence rate of 5.08%. The five cases of a single blood stream infection (BSI) shown in Table 2 were excluded from this analysis, as no meaningful inference could be drawn from such a small number of events.

No statistical association was found between healthcare-acquired UTI infection and length of stay but evidence was found that healthcare-acquired LRTI extended hospital stay by 2.58 days (95% Confidence Interval 1.80-3.69 days) and OTHER single sites of HAI extended stay

by 2.61 days (95% Confidence Interval 2.02-3.39) (7). Evidence was found that healthcare-acquired SSI infection prolonged length of stay by 2.51 days (95% Confidence Interval 1.27:4.92) (8) and that more than one HAI (i.e. MULTI) was associated with an increased stay of 21 days (95% Confidence Interval 17.3 to 25.1) (9).

The predicted number of cases of HAI and bed days lost, by state and territory and by site of infection, are presented for both the public and private hospital system in Tables 3 and 4.

TABLES 3 & 4 HERE

The number of bed days that would be lost to the hospital system if the overall rate increased by 1%, and the number of bed days gained from a 1% reduction in rates, are presented in Table 5.

TABLE 5 HERE

Discussion

The algorithm predicts 175,153 (95% Credible Interval 155,911:195,168) cases annually in the Australian healthcare system, 63% arise in public hospitals and the remainder in private hospitals. Approximately 80% of these cases occur in NSW, Victoria and Queensland and UTI is the most common site of infection followed by OTHER, MULTI, LRTI and SSI. Other data for the Australian setting suggest that 8.46% of surgical patients first present with a SSI after they have left hospital (8). The algorithm predicts 854,289 bed days (95% Credible Interval 645,091:1,096,244) are lost annually to HAI. Seventy four percent of these bed days are used treating the symptoms of patients who acquired more than one HAI during their admission to hospital. If rates increased overall by 1%, then a further 152,336 bed days would be lost. If rates are reduced by 1% overall, then 150,158 bed days are released for alternative

uses. Based on an average length of stay of 3.9 days for admission to public hospitals (11) approximately 38,500 new admission could be made with these bed days each year.

All modelling studies are a simplification of the real world and are characterised by uncertainty in their conclusions (12). One limitation of this study is that the parameters were informed by data collected from one public tertiary referral hospitals and one public district general hospital in south-east Queensland in 2002/2003 (7-9). We are uncertain whether rates are stable across states and territories, across the public/private divide or whether rates have changed since 2002/03. It is difficult to find other data with which to validate these findings. Routinely coded ICD-10 data could be used but they have poor sensitivity and specificity for HAI (13). Our method did characterise the variation around the estimates used and so uncertainty in the parameters was propagated forward to the conclusions. Repeating data collection in each state and territory might not be justified as the findings may not change much. A further caveat is that we excluded blood stream infections (BSI) as only 5 cases were observed in the primary study (7-9); this number was too small to allow any meaningful inference to be drawn about the association between single BSI and length of stay. There were a number of BSIs among the patients who has MULTI HAIs (9). BSI is a rare but serious problem in Australian hospitals. Data published in 2005 show they occur at a rate of 3.7 per 1,000 central venous catheter days (14).

The algorithm used was simple and followed a logical structure. We only included admissions to the clinical specialties included in the primary epidemiological study (7-9) (see Appendix 2), and these account for 52% of all admissions to the public hospital system. We excluded patient groups with potentially complex diagnoses and uncertain outcomes, for example: transplant, plastic surgery, medical oncology, obstetrics, extensive burns, neonates, haematology, chemotherapy, renal medicine, dialysis and neurosurgery. HAI could be a major

problem in these subgroups but the purpose of our study is to describe the epidemiological and economic outcomes for high-volume medical and surgical cases. We also excluded patients with a low risk of HAI, for example, patients admitted to: dermatology, diagnostic gastrointestinal endoscopy, pain management, dentistry, ophthalmology, tracheostomy, perinatology, drug and alcohol, psychiatry, non-acute psychiatry, rehabilitation, palliation and psychogeriatric.

These results are useful for two reasons. The first is to demonstrate the gross costs of HAI. The second, and much more useful reason, is to inform economic arguments for programmes that reduce rates of HAI. Some interpretation of the costs of HAI is required for both of these purposes. We have chosen to use the currency of 'bed days' to describe the economic costs of HAI. The reason is that most financial expenditures made in the hospital sector are fixed within a twelve-month budgeting cycle (15, 16). Preventing infections will not release much cash, instead bed days will be released. Assessing the dollar value of the marginal bed-day is difficult. Some insight is provided by the facts that Australian policy makers allocated resources valued at $14,470 million to supply 14,391 hospital bed days in 2004/05 (1). Based on these data, the mean valuation of a bed day is $1,005. By applying this figure to the results of this study we see a gross economic burden of HAI of $942,112,531 (95% Credible Interval $694,829,471: $1,206,448,693). This number should be interpreted with caution. Policy makers appear to value bed days - at current rates of HAI - at $1,005, yet, they might value marginal bed days released by expended infection-control differently. As more bed days become available from the prevention of HAI, then the valuation may diminish. The real economic value depends on the decision makers' willingness to pay for extra bed days. One consideration is that faster throughput will change variable costs and may even increase cost associated with infection from MRSA organisms due to increased risk of transmission between patients via healthcare workers (17).

Current infection control activities among Australian hospitals are valuable. We showed a 1% increase in rates would lead to an additional loss of 150,158 bed days. In other settings such as Argentina, where infection control is less rigorous or even absent, rates of 90 infections per 1,000 bed days have been shown in the ICU (18). It is not known whether investing additional resources for infection control would lead to improved cost-effectiveness among hospitals (19, 20), yet methods for economic appraisal in this area have been described (21, 22). Indeed, between 10-70% of all HAI can be prevented (23) depending on setting, baseline infection rates and type of infection. Research on whether additional infection control in Australia is cost-effective should be conducted. High quality modelling studies that synthesise evidence from meta-analyses, clinical studies and routine data sources can be used (24). The problem of HAI is substantial and a range of interventions can be used to reduce rates and improve patient outcomes. There exists potential to improve efficiency in the Australian hospital sector by reducing rates of HAI.

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Table 1. The total number of patients admitted to Australian hospital in 2004-05 and the number of surgical admissions

	Patients at risk of any healthcare acquired infection		Surgical patients at risk of surgical site healthcare acquired infection	
	Public hospitals	Private Hospitals	Public hospitals	Private Hospitals
NSW	741,784	354,558	365,944	288,812
VIC	611,721	324,902	305,663	235,175
QLD	379,744	304,971	193,237	210,433
WA	184,176	138,288	96,055	102,676
SA	188,990	103,737	97,462	78,262
Tas	46,148	0	22,425	0
ACT	30,230	0	16,604	0
NT	28,815	0	13,223	0
Total	2,211,608	1,226,456	1,110,613	915,358

Table 2. The number of cases of healthcare acquired infections, denominators and incidence rates for 95 days found in two Australian hospitals.

	Incidence Rate for 95 days	Number of cases	At risk population (combined Incidence Rate)
UTI	1.76%	79	4,488 (4.68%)
LRTI	0.82%	37	
OTHER	1.09%	49	
MULTI	0.89%	40	
BSI	0.11%	5	
SSI	1.1%	18	1,640 (1.1%)

Sources (7-9), UTI = healthcare acquired urinary tract infection, LRTI = healthcare acquired lower respiratory tract infection, OTHER = healthcare acquired other single site of infection (6 in the digestive system, 2 in the ear, 6 in the mouth and/or oesophagus, 1 in pleural fluid, 10 at an intravenous catheter insertion site, 18 involving skin, and 6 at an unknown site), MULTI = more than one healthcare acquired infection, BSI = healthcare acquired bloodstream infection, SSI = healthcare acquired surgical site infection. Overall Incidence rate of 5.08% arises from: 228/4488; alternatively, 4.68% + 1.1%*(1640/4,488).

Table 3. The number of cases of HAI, by state and territory and site of infection, 2004/05, and the percentage of cases in public hospitals.

	UTI (95% CrI)	LRTI (95% CrI)	OTHER (95% CrI)	MULTI (95% CrI)	SSI (95% CrI)	ALL HAI (95% CrI)
NSW	18,722 (15,394:22,126), 67%	8,892 (6,541:11,437), 67%	11,719 (9,115:14,645), 67%	9,582 (7,220:12,115), 67%	7,075 (4,607:10,055), 56%	55,989 (49,823:62,412), 66%
VIC	16,019 (13,171:18,932), 65%	7,608 (5,597:9,785), 65%	10,027 (7,799:12,531), 65%	8,199 (6,178:10,366), 65%	5,850 (3,808:8,313), 56%	47,701 (42,466:53,129), 64%
QLD	11,683 (9,607:13,808), 55%	5,549 (4,082:7,137), 55%	7,313 (5,689:9,139), 55%	5,980 (4,506:7,561), 55%	4,357 (2,836:6,191), 48%	34,882 (31,049:38,869), 54%
WA	5,521 (4,540:6,525), 57%	2,622 (1,929:3,373), 57%	3,456 (2,688:4,319), 57%	2,826 (2,129:3,573), 57%	2,151 (1,401:3,057), 48%	16,576 (14,741:18,483), 56%
SA	4,990 (4,103:5,898), 64%	2,370 (1,744:3,049), 64%	3,124 (2,430:3,904), 64%	2,554 (1,925:3,229), 64%	1,896 (1,235:2,695), 55%	14,934 (13,290:16,650), 63%
TAS	782 (643:924), 100%	371 (273:478), 100%	489 (381:612), 100%	400 (301:506), 100%	240 (156:341), 100%	2,282 (2,034:2,542), 100%
ACT	511 (420:604), 100%	243 (179:312), 100%	320 (249:400), 100%	262 (197:331), 100%	177 (115:252), 100%	1,512 (1,346:1,683), 100%
NT	493 (405:583), 100%	234 (172:301), 100%	309 (240:386), 100%	252 (190:319), 100%	143 (93:203), 100%	1,431 (1,276:1,592), 100%
Total	58,671 (48,241:69,339), 64%	27,865 (20,499:35,840), 64%	36,724 (28,566:45,895), 64%	30,028 (22,626:37,968), 64%	21,865 (14,236:31,072), 55%	175,153 (155,911:195,168), 63%

CrI = Credible Interval

Table 4. The number of bed days lost to HAI, by state and territory and by site of infection, 2004/05, and the percentage in public hospitals.

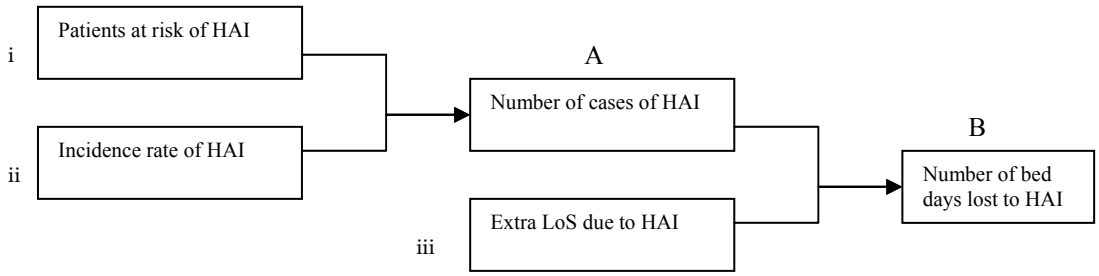
	LRTI (95% CrI)	OTHER (95% CrI)	MULTI (95% CrI)	SSI (95% CrI)	ALL HAI (95% CrI)
NSW	22,761 (8,001:44,052), 67%	30,569 (11,986:57,383), 67%	202,190 (144,868:269,439), 67%	17,324 (4,529:37,243), 56%	272,844 (205,990:350,143), 67%
VIC	19,475 (6,846:37,692), 65%	26,156 (10,256:49,098), 65%	172,998 (123,952:230,537), 65%	14,323 (3,744:30,791), 56%	232,951 (176,068:299,086), 65%
QLD	14,204 (4,993:27,491), 55%	19,077 (7,480:35,810), 55%	126,178 (90,406:168,145), 55%	10,667 (2,788:22,933), 48%	170,126 (128,462:218,315), 55%
WA	6,712 (2,359:12,991), 57%	9,015 (3,535:16,922), 57%	59,625 (42,721:79,456), 57%	5,267 (1,377:11,324), 48%	80,619 (60,791:103,500), 56%
SA	6,067 (2,133:11,742), 64%	8,148 (3,195:15,296), 64%	53,895 (38,616:71,821), 64%	4,643 (1,214:9,981), 55%	72,753 (54,920:93,359), 64%
TAS	950 (334:1839), 100%	1,276 (500:2,396), 100%	8,442 (6,049:11,250), 100%	588 (154:1,264), 100%	11,257 (8,511:14,386), 100%
ACT	621 (218:1202), 100%	834 (327:1566), 100%	5,518 (3,954:7,353), 100%	434 (114:0,933), 100%	7,408 (5,605:9,497), 100%
NT	599 (211:1160), 100%	805 (316:1511), 100%	5,324 (3,815:7,095), 100%	350 (92:753), 100%	7,079 (5,350:9,049), 100%
Total	71,328 (25,074:138,051), 64%	95,799 (37,563:179,828), 64%	633,626 (453,991:844,372), 64%	53,536 (13,995:115,092), 55%	854,289 (645,091:1,096,244), 64%

CrI = Credible Interval

Table 5. The change in the number of bed days available to the hospital system from a 1% increase/decrease in overall infection rates

		LRTI	OTHER	MULTI	SSI	ALL HAI
NSW	1% decrease	4,111	5,230	35,648	3,673	48,661
	1% increase	-4,281	-4,931	-36,296	-2,441	-47,949
VIC	1% decrease	3,517	4,475	30,501	3,036	41,530
	1% increase	-3,663	-4,219	-31,056	-2,018	-40,956
QLD	1% decrease	2,565	3,264	22,246	2,261	30,337
	1% increase	-2,672	-3,077	-22,651	-1,503	-29,903
WA	1% decrease	1,212	1,542	10,512	1,117	14,384
	1% increase	-1,262	-1,454	-10,704	-0,742	-14,162
SA	1% decrease	1,096	1,394	9,502	984	12,976
	1% increase	-1,141	-1,314	-9,675	-654	-12,785
TAS	1% decrease	172	218	1488	125	2003
	1% increase	-179	-206	-1516	-83	-1983
ACT	1% decrease	112	143	973	92	1320
	1% increase	-117	-135	-991	-61	-1303
NT	1% decrease	108	138	939	74	1259
	1% increase	-113	-130	-956	-49	-1248
Total	1% decrease	12,882	16,391	111,714	11,349	152,336
	1% increase	-13,416	-15,454	-113,746	-7,542	-150,158

Figure 1. The process used to describe two main outcomes marked A and B.



Appendix 1. Method used to fit probability distributions

A beta distribution was fitted for the incidence rates because it is restricted to the interval 0-1, represents a good fit to the binomial distribution and is continuous. The number of patients with an HAI (i.e. events) and the number of patients without an HAI (i.e. non-events) was used to inform the two non-negative shape parameters, α and β.

A gamma distribution was fitted for the increase in length of stay due to a diagnosis of HAI. The gamma is constrained on the interval 0 to positive infinity and is appropriate for the skew found in resource-use data, such as cost and length of stay. The method of moments was used to fit this distribution with the expected value and variance of the distribution given by, $E[0] = \alpha\beta$ and $\text{var}[0] = \alpha\beta^2$. We set the observed sample mean and variance reported in three studies by Graves et al. (7-9) equal to the expressions of the mean and variance for the Gamma distribution with the re-arranged expressions solved as follows, $\alpha = \frac{\bar{u}^2}{s^2}$ and $\beta = \frac{s^2}{\bar{u}}$.

Appendix 2. Clinical specialties included in the primary epidemiological study

Breast endocrine and thoracic, Cardiac surgical unit, Cardiology, Colorectal, Diabetes/endocrine, Ear nose and throat, Gastroenterology, General medicine, Geriatric, Gynecology, Hepato-pancreato-biliary, Infectious diseases, Intensive care unit, Medical stroke unit, Neurology, Orthopedic, Respiratory, Rheumatology, General surgical unit, Upper gastrointestine and soft tissue, Urology, Vascular, Women's and children's health.